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Physico-chemical properties of tobacco growing soils of Prakasam district, Andhra Pradesh

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Abstract
The present study was carried out by collecting 100 representative soil samples from tobacco growing soils of Prakasam district. The soils were found to be neutral to moderately alkaline in reaction. All the soil samples were non-saline. $CaCO_3$ ranged from nil to medium. The soils of the region were low to medium in organic carbon. The exchangeable calcium was found to be the most dominant cation followed by magnesium, potassium and sodium on soil complex. The cation exchange capacity of the soils varied from 7.80 to 49.26 with a mean of 31.83 cmol (p^+) kg^{-1}. The soils showed the mean values of per cent saturation of Ca, Mg, K and Na were 64.93, 12.37, 8.21 and 7.10 which ranged from 38.75 to 81.34, 2.04 to 24.29, 3.14 to 33.33 and 2.23 to 12.82, respectively. The average per cent base saturation was 93.05 which varied from 67.69 to 99.50.

Keywords: tobacco growing soils, zinc, iron, manganese, copper

Introduction
Tobacco, a quality conscious commercial crop is grown on the soils of Prakasam district. The tobacco growing area in Prakasam district was 71,593 ha. sustainable agriculture production. Tobacco also called "Golden leaf" is one of the important commercial crops of India being so it is vital to the economy. The wide variation in the physico-chemical properties of the soil. These properties influence the type, grade and quality of tobacco produced.
The knowledge about the limitations related to soil fertility would help us making accurate fertilizer recommendation to the tobacco farmers. This would also help in increasing the yield of the major crops of the area like tobacco. Keeping all these points in view, the study was conducted in tobacco growing areas covering eight mandals of Prakasam district, Andhra Pradesh. The present investigation is formulated with the following objectives.

Materials and Methods
Survey was conducted in the tobacco growing areas of Prakasam district covering eight mandals during the month of June, 2014 and collected one hundred representative surface soil samples (0-15 cm) from farmer's fields. Soil reaction was determined in 1:2.5 soil water suspension using glass electrode pH meter and the conductivity was estimated using Wheatstone conductivity bridge (Jackson, 1973) [9].
Organic carbon content of the soils was determined by wet digestion method of Walkley and Black as described by Jackson (1973) [9]. Free calcium carbonate content of soils was determined by neutralization with an acid (Schollenberger, 1945) [24].
A known weight of the soil sample was saturated with1 N sodium acetate (pH 8.3). The excess sodium acetate was leached out by washing out with 95% ethanol. Then the adsorbed sodium was displaced with neutral normal ammonium acetate. The concentration of sodium in the leachate was estimated flamephotometrically. The CEC was calculated and expressed as cmole (p^+) kg^{-1} soil (Bower *et al*., 1952) [3].
Exchangeable cations were extracted by centrifuge extraction procedure using neutral normal ammonium acetate as described by Bower *et al*. (1952) [3]. The sodium (Na^+) and potassium (K^+) ions were determined in the extract by aspirating directly into flame photometer, where as calcium (Ca^{+2}) and magnesium (Mg^{+2}) ions were determined by versanate titration method (Jackson, 1973) [9].
The Exchangeable sodium percentage of soils is the extent to which the adsorption complex of a soil is occupied by sodium, which is computed by the following equation (CSSRI, 2004).

$$ESP = \frac{\text{Exchangeable sodium (cmol } (p^+) \text{ kg}^{-1})}{\text{Cation exchange capacity (cmol } (p^+) \text{ kg}^{-1})} \text{ X } 100$$

It is defined as the extent to which the exchange complex of a soil is saturated with exchangeable basic cations and it is expressed as percentage of the total cation exchange capacity. The per cent base saturation of the soils was computed by the formula.

$$PBS = \frac{\text{Cmol } (p^+) \text{ of basic cations kg}^{-1}}{\text{Total CEC in cmol } (p^+) \text{ kg}^{-1}} \text{X } 100$$

Results and Discussion

1. Soil Reaction

Results pertaining to the pH of tobacco growing soils of Prakasam district presented in table 1.

Table 1: Physico-chemical properties of tobacco growing soils of Prakasam district

S.No	Name of the mandal	pH		EC (dS m^{-1})		OC (%)		$CaCO_3$ (%)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Naguluppalapadu	7.4-8.2	7.7	0.14-0.34	0.20	0.16-0.48	0.31	0.00-10.00	3.76
2	Ongole	7.4-8.4	7.9	0.12-0.71	0.31	0.01-0.71	0.23	0.00-12.50	6.39
3	Santhanuthalapadu	7.6-8.2	7.9	0.20-0.31	0.27	0.20-0.35	0.24	2.00-12.30	8.33
4	Tanguturu	7.2-8.0	7.5	0.19-0.55	0.35	0.19-0.55	0.35	0.00-5.00	1.21
5	Kandukuru	7.4-8.0	7.7	0.15-0.78	0.28	0.15-0.45	0.31	0.00-6.00	3.13
6	Jarugumalli	7.4-7.9	7.7	0.11-0.80	0.39	0.23-0.64	0.36	0.00-6.00	3.33
7	Maddipadu	7.4-8.0	7.6	0.10-0.30	0.20	0.01-0.67	0.32	0.00-7.60	2.16
8	Korisapadu	7.3-8.0	7.6	0.12-0.27	0.17	0.15-0.87	0.37	0.00-5.00	2.34
	Overall	7.2-8.4	7.7	0.10-0.80	0.27	0.01-0.87	0.31	0.00-12.50	3.90

The pH of soils of Naguluppalapadu mandal ranged from 7.4 to 8.2 with a mean value of 7.7. The average pH in the soils of Ongole mandal varied from 7.4 to 8.4 and had a mean of 7.9. The pH varied between 7.6 and 8.2 with a mean of 7.9 in soils of Santhanuthalapadu mandal. The soils of Tanguturu mandal showed range and mean pH values as 7.2 to 8.0 and 7.5, respectively. In Kandukuru mandal, the observed range and mean of soil pH were 7.4 to 8.0 and 7.7, respectively. The range and mean pH values in soils of Jarugumalli mandal were found to be 7.4 to 7.9 and 7.7, respectively. The average pH in the soils of Maddipadu mandal was 7.6 which varied from 7.4 to 8.0. The pH in soils of Korisapadu mandal ranged from 7.3 to 8.0 with mean value of 7.6.

The analytical data of soil samples revealed that the pH of studied mandals in Prakasam district ranged from 7.2 to 8.4 with mean of 7.7. About 4 per cent soil samples were under neutral (6.6-7.3), 70 per cent samples were mildly alkaline (7.4-7.8) and remaining 26 per cent were under moderately alkaline (7.9-8.4) in reaction according to Brady (2000). Those soils which were neutral to moderately alkaline in reaction which could be attributed to accumulation of clay, bases and lime. The pH had significant positive correlation with $CaCO_3$ (r=0.856**), Ca (r=0.657**), Mg (r=0.424**), Na (r=0.783**), PBS (r=0.503**), CEC (r=0.685**), ESP (r=0.618**), clay (r=0.654**) and clay+silt (r=0.572**) and negative correlation (r=-0.565**) with sand. Similar results were obtained by Venkateswarlu *et al*. (1995) [27] in black soils of Kandukuru division and Ram *et al*. (2014a) [17] in soils of Markapur mandal, Prakasam district.

2. Electrical Conductivity (dS m^{-1})

The data pertaining to electrical conductivity of tobacco growing soils of Prakasam district are presented in table 1.

The electrical conductivity of soil samples in Naguluppalapadu mandal ranged from 0.14 to 0.34 with a mean of 0.20 dS m^{-1}. The range and mean of EC in the soils of Ongole mandal were recorded as 0.12 to 0.71 and 0.31 dS m^{-1}, respectively. In Santhanuthalapadu mandal, the EC of soil samples varied from 0.20 to 0.31 with a mean of 0.27 dS m^{-1}.The range and mean values of EC in Tanguturu mandal was found to be 0.19 to 0.55 and 0.35 dS m^{-1}, respectively.

The soils of Kandukuru mandal showed a range and mean EC values of 0.15 to 0.78 and 0.28 dS m^{-1}, respectively. The range of EC in soils of Jarugumalli mandal varied from 0.11 to 0.80 with mean of 0.39 dS m^{-1}.The range and mean of EC was 0.10 to 0.30 and 0.20 dS m^{-1} in soils of Maddipadu mandal. The EC varied from 0.12 to 0.27 with a mean of 0.17 dS m^{-1} in soils of Korisapadu mandal.

The data presented in table 1 indicated that EC of soil samples varied from 0.10 to 0.80 with a mean value of 0.27 dS m^{-1}. The results revealed that 100 per cent samples were under normal category according to Department of Agriculture, Andhra Pradesh (2007) [6]. Non-saline nature of these soil samples might be due to agricultural practices. The agricultural practices were continuous preparatory cultivation that leads to movement of salts to the subsrface layers. Then after evevn small rainfall occurs the soluble salts move in to the deeper layers (Pulakeshi *et al*. 2014) [16]. The less soluble salt content indicated that the suitability of these soils for tobacco cultivation. These results were in accordance with the findings of Venkateswarlu *et al*. (1995) [27] in soils of Kandukuru division, Ramesh *et al*. (1997) [20] in soils of Prakasam district, Krishnamurthy *et al*. (2007) [12, 21] for tobacco growing soils of Periyapatna in Mysore district, Karnataka and Rao and Krishnamurthy *et al*. (2007) [12, 21] in soils of Khammam district.

3. Organic Carbon (%)

The data related to organic carbon are presented in table 1. In soils of Naguluppalapadu mandal, the organic carbon content ranged from 0.16 to 0.48 with mean value of 0.31 per cent. The range and mean of organic carbon noticed in soils of Ongole mandal was 0.01 to 0.71 and 0.23 per cent, respectively. The average organic carbon content in soils of Santhanuthalapadu mandal was 0.24 which varied from 0.20 to 0.35 per cent. While the organic carbon content varied from 0.12 to 0.71 with mean of 0.35 per cent in soils of Tanguturu mandal.

In soils of Kandukuru mandal, the discernible ranges of organic carbon content were in between 0.15 and 0.45 with a mean of 0.31 per cent. The observed range of organic carbon in the soils of Jarugumalli mandal was 0.23 to 0.64 with a mean of 0.36 per cent. In soils of Maddipadu mandal the organic carbon content ranged from 0.01 to 0.67 with a mean of 0.32 per cent. Range and mean values of organic carbon of

the soils of Korisapadu mandal were 0.15 to 0.87 and 0.37 per cent, respectively.

The organic carbon content varied from 0.01 to 0.87 with a mean value of 0.31 per cent. The soils of mandals under study of Prakasam district found to be low to medium in organic carbon content. As per ratings given by Ramamoorthy and Bajaj (1969) [19], 95 per cent samples were found to be low and remaining 5 per cent were medium. Low organic carbon content in these soils might be due to rapid oxidation of organic matter in semi-arid climatic conditions and less application of organic manures like FYM, compost (Krishnamurthy *et al*., 1981) [12, 21]. These results were similar with the findings of Ratnam *et al*. (2001) [22] in soils of Ulavapadu mandal of Prakasam district, Krishnamurthy and Chandra (2002) [12, 21] in tobacco growing soils of northern light soils and Krishnamurthy and Singh (2003) [12, 21] in tobacco growing soils of Andhra Pradesh.

4. Calcium Carbonate (%)

The data related to calcium carbonate content in tobacco growing soils of Prakasam district are presented in table 1.

The calcium carbonate content in soils of Naguluppalapadu mandal ranged from nil to 10.00 with a mean value of 3.76 per cent. In soils of Ongole mandal the discernible ranges of $CaCO_3$ content were in between nil and 12.50 with a mean of 6.39 per cent. The observed range of $CaCO_3$ in the soils of Santhanuthalapadu mandal varied from 2.00 to 12.30 with a mean of 8.33 per cent. The average $CaCO_3$ content in soils of Tanguturu mandal was 1.21 which ranged from nil to 5.00 per cent.

The range of $CaCO_3$ analysed in soils of Kandukuru mandal was nil to 6.00 with mean of 3.13 per cent. The soils of Jarugumalli mandal showed range and mean $CaCO_3$ values as nil to 8.00 and 3.33 per cent, respectively. The mean $CaCO_3$ observed in soils of Maddipadu mandal was 2.16 which varied from nil to 7.60 per cent. The $CaCO_3$ content varied from nil to 5.00 with a mean value of 2.51 per cent, respectively in soils of Korisapadu mandal.

The data in table 1 indicated that $CaCO_3$ content in the tobacco growing soils of Prakasam district ranged from nil to 12.50 per cent with a mean of 3.90 per cent. These findings were in accordance with the earlier findings of Jamuna *et al*. (1984) [10] and Ram *et al*. (2014a) [17]. Some of the soils had calcium carbonate accumulated and remaining soils did not have any accumulation of calcium carbonate content. The data revealed that 62 per cent soil samples were low in $CaCO_3$ and remaining 38 per cent soils were medium in $CaCO_3$ content according to the limits of Tamgadge *et al*. (1996). This wide variation was due to variation in pH, clay content of soil and soil forming factors and procedures. $CaCO_3$ accumulation was mainly due to calcification, a pedogenic process in semi-arid climate (Venkateswarlu *et al*. 1995) [27].

$CaCO_3$ showed significant positive correlation with CEC (r=0.678**), clay (r=0.612**), clay+silt (r=0.537**), PBS (r=0.504**) while negative correlation with sand (r=-0.535**). Similar results were reported by Jamuna *et al*. (1984) [10] in soils of Prakasam district and Ram *et al*. (2014a) [17] in different physographic divisions in soils of Markapur mandal of Prakasam district.

5. Cation Exchange Capacity

The data related to cation exchange capacity in tobacco growing soils of Prakasam district were presented in table 2.

The range and mean of cation exchange capacity values in soils of Naguluppalapadu mandal were 21.50 to 48.00 and 32.80 cmol (p^+) kg^{-1}, respectively. Whereas, in soils of Ongole mandal the cation exchange capacity ranged from 19.50 to 49.26 with a mean of 37.25 cmol (p^+) kg^{-1}.The average cation exchange capacity in soils of Santhanuthalapadu was 37.65 and varied from 30.50 to 47.00 cmol (p^+) kg^{-1}. The cation exchange capacity ranged from 7.80 to 47.00 with a mean value of 24.14 cmol (p^+) kg^{-1} in soils of Tanguturu mandal.

Table 2: Available micronutrient status of tobacco growing soils of Prakasam district

S.No	Name of the mandal		Exchangeable bases (cmole (p^+) kg^{-1})					CEC (cmole (p^+) kg^{-1})
			Ca^{2+}	Mg^{2+}	K^+	Na^+	Total bases	
1	Naguluppalapadu	Range	13.20-33.50	2.00-7.80	1.90-3.20	1.00-3.70	19.10-47.30	21.50-48.00
		Mean	23.19	3.89	2.51	2.10	31.70	32.80
2	Ongole	Range	13.00-35.80	1.00-6.70	1.20-3.60	0.80-4.80	18.60-48.70	19.50-49.26
		Mean	26.94	3.76	2.57	2.63	35.91	37.25
3	Santhanuthalapadu	Range	18.40-31.20	3.90-8.50	1.10-4.90	2.70-5.00	28.80-45.40	30.50-47.00
		Mean	24.41	6.11	2.36	3.53	36.41	37.65
4	Tanguturu	Range	3.10-30.00	0.20-8.40	1.40-4.10	0.20-5.40	5.30-46.20	7.80-47.00
		Mean	14.56	3.17	2.75	1.56	22.04	24.14
5	Kandukuru	Range	12.00-29.00	0.80-5.60	1.43-4.10	1.00-5.00	19.40-38.00	23.40-39.20
		Mean	19.43	2.77	2.75	2.46	27.40	29.67
6	Jarugumalli	Range	14.10-26.00	1.40-5.90	1.10-3.10	1.00-4.70	20.70-35.40	25.70-36.89
		Mean	20.78	4.44	2.03	2.38	29.63	31.98
7	Maddipadu	Range	13.10-28.50	2.50-6.20	1.00-3.30	1.00-3.50	20.10-38.10	24.60-39.50
		Mean	18.75	4.18	2.24	2.14	27.31	30.53
8	Korisapadu	Range	12.80-25.20	2.50-5.00	1.90-3.30	1.00-3.80	20.70-35.00	23.50-36.00
		Mean	17.99	3.97	2.35	1.94	26.25	28.53
	Overall range		3.10-35.80	0.20-8.50	1.00-4.90	0.20-5.40	5.30-48.70	7.80-49.26
	Overall mean		21.01	4.05	2.44	2.36	29.86	31.83

The soils of Kandukuru mandal showed range and mean of cation exchange capacity values as 23.40 to 39.20 and 29.67 cmol (p^+) kg^{-1}, respectively. The cation exchange capacity in soils of Jarugumalli mandal varied from 25.70 to 36.89 with mean value of 31.98 cmol (p^+) kg^{-1}. The cation exchange capacity range and mean in soils of Maddipadu mandal were 24.60 to 39.50 and 30.53 cmol (p^+) kg^{-1}, respectively. The cation exchange capacity noticed in Korisapadu mandal varied from 23.50 to 36.00 with mean of 28.53 cmol (p^+) kg^{-1}.

The average cation exchange capacity in soils of surveyed mandals varied from 7.80 to 49.26 with mean of 31.83 cmol (p^+) kg^{-1}. Relatively higher CEC values were observed in soils

of clay texture followed by sandyclay, clay loam, sandy clay loam and loamy sand. The high cation exchange capacity might be due to accumulation of clay and presence of smectitic type of clay minerals (Das, 1999). Cation exchange capacity had significant positive correlation with clay (r=0.922**), clay+silt (r=0.832), WHC (r=0.936**) and Na (r=0.778**) because the soils were highly base saturated (Venkateswarlu *et al*. 1995) [27]. The findings were in accordance with the works of Govindarajan and Hirekerur (1971) [8], Ram *et al*. (2014a) [17] and Ram *et al*. (2014b) [18].

6. Exchangeable Basic Cations

The data pertaining to exchangeable basic cations of tobacco growing soils of Prakasam district are presented in the Table 2.

The results further revealed that the contents of exchangeable cations were found to be in the order of Ca^{2+}> Mg^{2+} > K^+ > Na^+. These results were supported by Demiss and Beyene (2010) [5]. The low values of monovalents (Na^+, K^+) than that of divalents (Ca^{2+}, Mg^{2+}) were due to fact that monovalents were leached out easily than divalent which might be because of immobile nature of divalents (Ravikumar *et al*., 2009 and Pulakeshi *et al*., 2014) [23, 16]. The other reason could be due to presence of high proportion of smectitic clay having high CEC (Venkateswarlu *et al*., 1995) [27].

6.1 Exchangeable calcium

The average exchangeable calcium content of the soils of Naguluppalapadu mandal ranged from 13.20 to 33.50 with a mean value of 23.19 cmol (p^+) kg^{-1}. In soils of Ongole mandal the exchangeable calcium content ranged from 13.00 to 35.80 with a mean of 26.94 cmol (p^+) kg^{-1}. The mean of exchangeable calcium content was 24.41 which varied from 18.40 to 31.20 cmol (p^+) kg^{-1} in the soils of Santhanuthalapadu mandal. In soils of Tanguturu mandal the discernible ranges of exchangeable calcium content were in between 3.10 and 30.00 with a mean of 14.56 cmol (p^+) kg^{-1}. The observed range of exchangeable calcium content in the soils of Kandukuru mandal was 12.00 to 29.00 with a mean of 19.43 cmol (p^+) kg^{-1}. The exchangeable calcium content varied from 14.10 to 26.00 with a mean of 20.78 cmol (p^+) kg^{-1} in Jarugumalli mandal. In soils of Maddipadu mandal, the exchangeable calcium content ranged from 13.10 to 28.50 with a mean of 18.75 cmol (p^+) kg^{-1}. The soils of Korisapadu mandal showed range and mean of exchangeable calcium content values were 12.80 to 25.20 and 17.99 cmol (p^+) kg^{-1}, respectively.

Exchangeable calcium was found to be the most dominant cation on the exchangeable complex and ranged from 3.10 to 35.80 with mean value of 21.01 cmol (p^+) kg^{-1} in soils of surveyed mandals in Prakasam district. The higher calcium content might be due to the fact that Ca^{2+} showed the strongest relationship with all the species, comparing these ions (Ca^{2+}, Mg^{2+}, K^+ and Na^+). It was clear that Mg^{2+} was present in low amount than Ca^{2+} because of its mobility and accumulation of $CaCO_3$ content. These results were evidenced by positive correlation between exchangeable Ca and CEC (r=0.958**) which might be due to strong adsorption of Ca on the soil colloids (Demiss and Beyene, 2010) [5]. Correlation of Ca with clay, $CaCO_3$ and PBS were recorded as 0.860**, 0.632** and 0.747**, respectively. Similar results were observed by Pulakeshi *et al*. (2014) [16].

6.2 Exchangeable magnesium

In soils of Naguluppalapadu mandal, the exchangeable magnesium content ranged from 2.00 to 7.80 with mean value of 3.89 cmol (p^+) kg^{-1}, whereas in soils of Ongole mandal exchangeable magnesium ranged from 1.00 to 6.70 with mean of 3.76 cmol (p^+) kg^{-1}. The exchangeable magnesium content varied from 3.90 to 8.50 with average of 6.11 cmol (p^+) kg^{-1} in soils of Santhanuthalapadu mandal. The average exchangeable magnesium content noticed in soils of Tanguturu mandal was 3.17 which varied from 0.20 to 8.40 cmol (p^+) kg^{-1}.

The mean exchangeable magnesium was 2.77 which ranged from 0.80 to 5.60 cmol (p^+) kg^{-1} in soils of Kandukuru mandal. The soils of Jarugumalli mandal contained exchangeable magnesium that ranged from 1.40 to 5.90 with mean of 4.44 cmol (p^+) kg^{-1}. In soils of Maddipadu mandal, the exchangeable magnesium content varied from 2.50 to 6.20 with mean of 4.18 cmol (p^+) kg^{-1}.The mean of exchangeable magnesium was found in Korisapadu mandal was 3.97 which varied from 2.50 to 5.00 cmol (p^+) kg^{-1}.

Exchangeable magnesium was the second most dominant cation next to exchangeable calcium but higher than exchangeable sodium and exchangeable potassium. In tobacco growing soils of Prakasam district, the values ranged from 0.20 to 8.50 with mean value of 4.05 cmol (p^+) kg^{-1}. Exchangeable Mg was positively correlated with CEC (r=0.718**), clay (r=0.670**), clay+silt (r=0.592**) which might be due to adsoption on soil colloids. However, adsorption of Mg on soil colloids was less than Ca. Correlation between Mg and WHC was noticed as positive (r=0.647**). Similar results was observed by Ratnam *et al*. (2001) [22] and Demiss and Beyene (2010) [5].

6.3 Exchangeable potassium

The exchangeable potassium present in soils of Naguluppalapadu ranged from 1.90 to 3.20 with mean of 2.51 cmol (p^+) kg^{-1}. In the soils of Ongole mandal the average exchangeable potassium content was 2.57 which varied from 1.20 to 3.60 cmol (p^+) kg^{-1}. The soils of Santhanuthalapadu mandal were containing exchangeable sodium which, varied from 1.10 to 4.90 with a mean of 2.36 cmol (p^+) kg^{-1}. The average exchangeable potassium was 2.75 which varied from 1.40 to 4.10 cmol (p^+) kg^{-1} in soils of Tanguturu mandal.

The average exchangeable potassium content was 2.75 which varied from 1.43 to 4.10 cmol (p^+) kg^{-1} in soils of Kandukuru mandal. The soils of Jarugumalli mandal containing exchangeable potassium ranged from 1.10 to 3.10 with average of 2.03 cmol (p^+) kg^{-1}. The exchangeable potassium content of soils of Maddipadu mandal ranged from 1.00 to 3.30 with a mean of 2.32 cmol (p^+) kg^{-1}. The average exchangeable potassium in soils of Korisapadu mandal was 2.35 which ranged from 1.90 to 3.30 cmol (p^+) kg^{-1}.

Analytical data in respect of exchangeable potassium content of surveyed soils in Prakasam district revealed that it varied from 1.00 to 4.90 with mean value 2.44 cmol (p^+) kg^{-1}. The variation of exchangeable K in soil might be due to differences in their parent material, degree of weathering, clay content and K fixation capacity of the soils. The lower exchangeable K content compared to Ca^{2+}, Mg^{2+} in soils of Maharashtra might be due to slow weathering of mica and fixation of released K (Balpande *et al*., 2007) [2]. The exchangeable K content was more when compared to Na, because potassium ion was more strongly adsorbed to the site of negative charge since it had a smaller hydrated radius.

6.4 Exchangeable sodium

The mean value of exchangeable sodium was recorded as 2.10 which ranged from 1.00 to 3.70 cmol (p^+) kg^{-1} in soils of

Naguluppalapadu mandal. The exchangeable sodium varied from 0.80 to 4.80 with mean of 2.63 cmol (p^+) kg^{-1} in soils of Ongole mandal. The exchangeable sodium content of soils of Santhanuthalapadu mandal ranged from 2.70 to 5.00 with mean of 3.53 cmol (p^+) kg^{-1}. In the soils of Tanguturu mandal the sodium content varied from 0.20 to 5.40 with mean of 1.56 cmol (p^+) kg^{-1}.

In Kandukuru mandal the soils were containing exchangeable sodium which varied from 1.00 to 5.00 with mean of 2.46 cmol (p^+) kg^{-1}. The average exchangeable sodium was 2.38 which varied from 1.00 to 4.70 cmol (p^+) kg^{-1} in soils of Jarugumalli mandal. The soils containing exchangeable sodium varied from 1.00 to 3.50 with mean of 2.16 cmol (p^+) kg^{-1} in Maddipadu mandal. The average exchangeable sodium in soils of Korisapadu mandal was 1.94 which ranged from 1.00 to 3.80 cmol (p^+) kg^{-1}.

The exchangeable sodium in the present sudy area ranged from 0.20 to 5.40 with a mean of 2.36 cmol (p^+) kg^{-1}. Results reported that exchangeable Na was positively correlated with ESP (r=0.878**), clay (r=0.730**), clay+silt (r=0.711**), WHC (r=0.783) but negatively (r=-0.708**) correlated with sand.

7. Per cent saturation of basic cations

The data regarding to per cent saturation of basic cations in tobacco growing soils of Prakasam district are presented in the table 2.

The per cent saturation of exchangeable Ca, Mg, K and Na ranged from 61.40 to 75.84, 7.27 to 16.25, 5.34 to 13.49 and 3.37 to 10.72 with mean values of 70.60, 11.46, 7.96 and 6.31 per cent, respectively in soils of Naguluppalapadu mandal. In the soils of Ongole mandal the exchangeable Ca, Mg, K and Na saturation ranged from 65.57 to 81.34, 5.13 to 13.60, 4.79 to 10.82 and 2.23 to 12.82 with mean values of 72.06, 9.41, 7.20 and 7.07, respectively. The soils of Santhanuthalapadu containing exchangeable Ca, Mg, K and Na saturation which ranged from 60.33 to 72.96, 10.86 to 24.29, 3.14 to 11.42 and 8.57 to 10.75 with mean values of 64.70, 16.47, 6.15 and 9.32, respectively. The soils of Tanguturu mandal showed the mean of per cent saturation of exchangeable Ca, Mg, K and Na as 55.96, 10.41, 14.03 and 5.17 which ranged from 38.75 to 69.06, 2.55 to 17.87, 5.63 to 33.33 and 3.07 to 11.49 per cent, respectively.

The average per cent saturation of exchangeable Ca, Mg, K and Na in soils of Kandukuru mandal were 64.99, 9.36, 9.51 and 7.91which varied from 51.28 to 75.00, 2.04 to 15.82, 4.29 to 14.44 and 4.03 to 12.76 per cent. The per cent saturation of exchangeable Ca, Mg, K, Na ranged from 54.86 to 76.02, 4.09 to 19.34, 3.66 to 9.31 and 3.89 to 12.74 with mean values of 64.45, 14.13, 6.32 and 7.17, respectively in soils of Jarugumalli mandal. While in soils of Maddipadu mandal, the per cent saturation of exchangeable Ca, Mg, K, Na ranged from 46.10 to 72.15, 9.54 to 20.00, 3.29 to 13.41 and 4.07 to 10.14 with mean values of 61.12, 13.65, 7.50 and 6.83, respectively. In soils of Korisapadu mandal the per cent saturation of exchangeable Ca, Mg, K and Na were ranged from 54.47 to 70.79, 9.82 to 21.28, 6.11 to 11.79 and 3.37 to 10.00 with mean values of 62.52, 12.37, 8.21 and 7.10 per cent, respectively.

The soils under studied area of Prakasam district showed the mean values of per cent saturation of exchangeable Ca, Mg, K and Na as 64.93, 12.37, 8.21 and 7.10 which ranged from 38.75 to 81.34, 2.04 to 24.29, 3.14 to 33.33 and 2.23 to 12.82, respectively. These results were supported by Anjaneyulu and Raychaudhuri (1964) [1] and Gopalachari (1976) [7]. The percent sodium saturation or exchangeable sodium per centage ranged from 2.23 to 12.76. Similar results were recorded by Pulakeshi *et al.* (2014) [16]. The ESP showed significant positive correlation with clay (r=0.428**), clay+silt (r=0.505**), WHC (r=0.507**) and negatively (r=-0.500**) correlated with sand content.

8. Per cent base saturation

The data pertaining to per cent base saturation in tobacco growing soils of Prakasam district were presented in the table 3. The average per cent base saturation in soils of Naguluppalapadu mandal was 96.33 which ranged from 88.84 to 99.42 per cent. In soils of Ongole mandal, the per cent base saturation ranged from 89.01 to 99.51 with mean value of 95.74 per cent. The per cent base saturation ranged from 94.43 to 98.87 with mean of 96.64 per cent in soils of Santhanuthalapadu mandal. The mean per cent base saturation in soils of Tanguturu mandal was 88.95 which varied from 67.69 to 98.30 per cent.

The per cent base saturation in the soils of Kandukuru mandal ranged from 82.91 to 96.94 with mean of 91.78 per cent. In the soils of Jarugumalli mandal the per cent base saturation varied from 80.54 to 96.57 with mean of 92.08 per cent. The per cent base saturation varied from 80.40 to 96.57 with mean of 89.10 in soils of Maddipadu mandal. In the soils of Korisapadu mandal the per cent base saturation ranged from 87.89 to 97.22 with mean of 92.07.

The average per cent base saturation in studied area of Prakasam district was 92.82 which varied from 67.69 to 99.51. Similar base saturation values were recorded by Varaprasadarao *et al.* (2008) [26]. The PBS of soils was found to be significantly and positively correlate with Ca (r=0.747**), Mg (r=0.479**), Na (r=0.611**), clay (r=0.608**) clay+silt (r=0.783**) and WHC (r=0.761**). High base saturation might be due to moderately alkaline reaction and high $CaCO_3$ content, as the exchangeable complex of the soils were dominated by calcium and magnesium, which are main sources for base saturation. The other reason could be due to the presence of base contributing minerals such as smectite in black soils (Pal *et al*., 2006) [15].

Table 3: Available micronutrient status of tobacco growing soils of Prakasam district

S. No	Name of the mandal		Percent saturation				
			Ca^{2+}	Mg^{2+}	K^+	Na^+	Total PBS
1	Naguluppalapadu	Range	61.40-75.84	7.27-16.25	5.34-13.49	3.37-10.72	88.84-99.42
		Mean	70.60	11.46	7.96	6.31	96.33
2	Ongole	Range	65.57-81.34	5.13-13.60	4.79-10.82	2.23-12.82	89.01-99.51
		Mean	72.06	9.41	7.20	7.07	95.74
3	Santhanuthalapadu	Range	60.00-72.96	10.86-24.29	3.14-11.42	8.49-10.75	94.43-98.87
		Mean	64.70	16.47	6.15	9.32	96.64
4	Tanguturu	Range	38.75-69.06	2.55-17.87	5.63-33.33	3.07-11.49	67.69-98.30
		Mean	55.96	10.41	14.03	5.17	88.95

5	Kandukuru	Range	51.28-75.00	2.04-15.82	4.29-14.44	4.03-12.76	82.91-96.94
		Mean	64.99	9.36	9.51	7.91	91.78
6	Jarugumalli	Range	54.86-76.02	4.09-19.34	3.66-9.31	3.89-12.74	80.54-96.57
		Mean	64.45	14.13	6.32	7.17	92.08
7	Maddipadu	Range	46.10-72.15	9.54-20.00	3.29-13.41	4.07-10.14	80.40-96.57
		Mean	61.12	13.65	7.50	6.83	89.10
8	Korisapadu	Range	54.47-70.79	9.82-21.28	6.11-11.79	3.37-10.00	87.89-97.22
		Mean	62.52	12.37	8.21	7.10	92.07
	Overall range		38.75-81.34	2.04-24.29	3.14-33.33	2.23-12.82	67.69-99.51
	Overall mean		64.93	12.37	8.21	7.10	93.05

Conclusion

The soil reaction was found to be neutral to moderately alkaline with values ranging from 7.2 to 8.4 with mean of 7.7. The soils were non saline with EC values ranging from 0.1 to 0.8 dS m^{-1}. Soils were low in organic carbon varied from 0.01 to 0.87 per cent with nutrient index 1.05. Low to medium in calcium carbonate content ranged from nil to 12.50 per cent.

The exchangeable calcium was found to be the most dominant cation followed by magnesium, potassium and sodium on soil complex with mean values of 21.01, 4.05, 2.44 and 2.36 cmol (p^+) kg^{-1}, respectively. The mean cation exchange capacity value recorded in soils was 31.83 cmol (p^+) kg^{-1}. The exchangeable sodium percentage of soils ranged from 2.23 to 12.82. The average per cent base saturation of soils was 93.05 which varied from 67.69 to 99.50.

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